The Role of Offshore Aquaculture in Integrated Coastal Management

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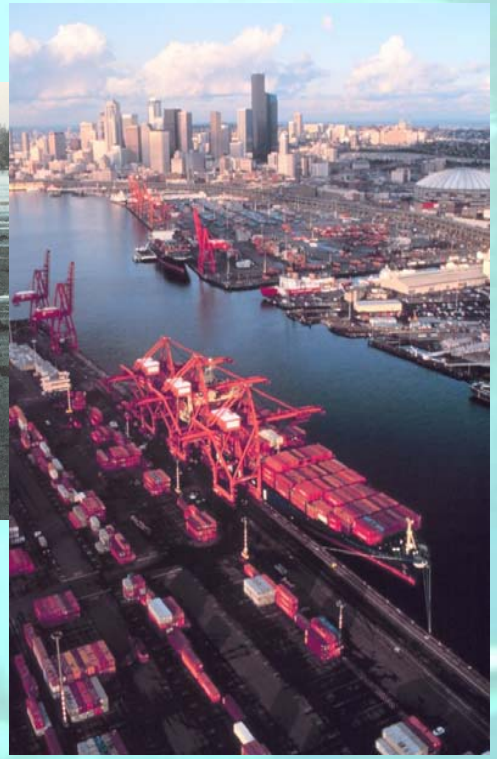
Multiple Human Activities impact the Coastal Zone



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Human Contributions to Eutrophication

- NITROGEN LOADING IN THE OCEAN HAS INCREASED 10 FOLD IN LAST CENTURY (WALSH 1988)
- AGRICULTURAL FERTILIZER PRODUCTION INCREASED FROM 10 M TONS IN 1950 TO 80 M TONS IN 1990 (BOUMAN 1999)
- FOSSIL FUELS CONTRIBUTE 20 M TONS N ON ANNUAL BASIS(BOUMAN 1999, SMITH 1999)
- DISSOLVED INORGANIC NITROGEN IN THE ENVIRONMENT IS DUE PRIMARILY TO AGRICULTURAL FERTILIZER(58%), HUMAN SEWAGE(24%) AND ATMOSPHERIC DEPOSITION (18%) (SEITZINGER AND KROEZE, 1998)

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Human Impacts on Fisheries

• OVEREXPLOITATION OF FISH STOCKS THREATEN SUSTAINABILITY OF FISHERIES AND SEAFOOD SUPPLY(FAO 1997)

• NMFS(2001) ESTIMATES THAT 92 FISHERIES STOCKS IN THE US ARE OVERFISHED COMPARED TO 148 STOCKS NOT OVERFISHED.

• NEW ENGLAND FISHERIES STOCKS ON GEORGE'S BANK AND IN MANY OTHER AREAS HAVE COLLAPSED AND THIS HAS LEAD TO SEVERE LOSS OF JOBS AND SEAFOOD SUPPLY

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Concept of Carrying Capacity

- Biological communities depend upon nutrients and these communities adapt to different levels of nutrients, higher nitrogen levels lead to higher processing rates for nitrogen. (Livingstone 2000)
- Carrying capacity for nutrients depends upon combination of physical, chemical and biological factors.
- Addition of nutrients can be beneficial or detrimental depending upon amount and location.
- Cumulative effects-5 fed aquaculture farms acceptable but 10 may not be depending on physical, chemical and biological factors plus location

Nutrient Role in Ocean Productivity

- Nutrients are essential for productive ecosystems
- WALSH (1988) estimates that 95% of the world fisheries production comes from coastal zones with upwelling and nutrient enrichment
- Average Pacific Ocean productivity is 1.25 KG/HA but maximum yield of 280KG/HA is off Peru in areas of upwelling

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Coastal Nutrient Carrying Capacity

- Christiansen, et.al (2000) observed that denitrification processes can remove 50% of nitrogen loading from a typical Norwegian fjord.
- Newell (1988) estimated that early, unexploited, oyster populations in Chesapeake Bay could filter entire volume of the bay in less than a week.
- Living marine resources in coastal waters have a profound effect on the assimilative and recycling capacity for nutrients.

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Nearshore Verses Offshore Aquaculture

- Coastal areas that are shallow, with limited circulation are already impacted by eutrophication.
- Offshore areas have much larger volumes of water and greater biological and physical capacity for nutrients.
- Nutrients in more offshore locations can stimulate fisheries.

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Examples of Ecological Function by Biota

- Chesapeake Bay managers are spending millions to increase oysters in order to improve water quality in the bay.
- Zebra mussels in Lake Erie have led to dramatic improvements in water clarity(good or bad)
- Clam aquaculture on the eastern shore of the CB has led to improved water clarity and increase in SAV.
- Created wetlands and SAV restoration have documented ecological functions

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Types of Aquaculture by Function

- Extractive Aquaculture (Nutrient removal)
  - Filter Feeder Mollusks
  - Algae

- Fed Aquaculture (Nutrient addition)
  - Shrimp
  - Finfish culture

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Function of Bivalve Filter Feeders

- Individual bivalves can filter 1 to 4 liters per individual per hour. Bivalves filter particles including phytoplankton, detritus, silt and clay(Jorgensen, 1966)
- Rice 2001) calculated that quahog clams could filter 21% of tidal volume of Providence River on each tide. This increased light penetration.
- Hard clams excrete about 9 mg NH3 kg-1 of soft tissue per day but for every kilogram of shellfish meat harvested about 16 grams of Nitrogen are removed (Rice 1999) This knowledge allows modeling.

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Role of Marine Plants in balanced ecosystem

- Production of seaweeds and animals compliment one another(Chopin 2002)
- China produces 4.8 million tons of marine algae annually which removes 60-100,000 tons of nitrogen upon harvest (Fei 1998)
- Porphyra, nori, responds to higher levels of P and N in the environment by absorbing more. (Fei 1998)

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Long line cultivation of *Laminaria japonica*

(b. courtesy of E. Hwang)

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Open water Cultivation and harvest of *Kappaphycus*

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Seaweed farming low technology methods

Photos: Dr A Hurtado SEAFDEC

Undaria culture in Korea

Photo- Dr. Huang

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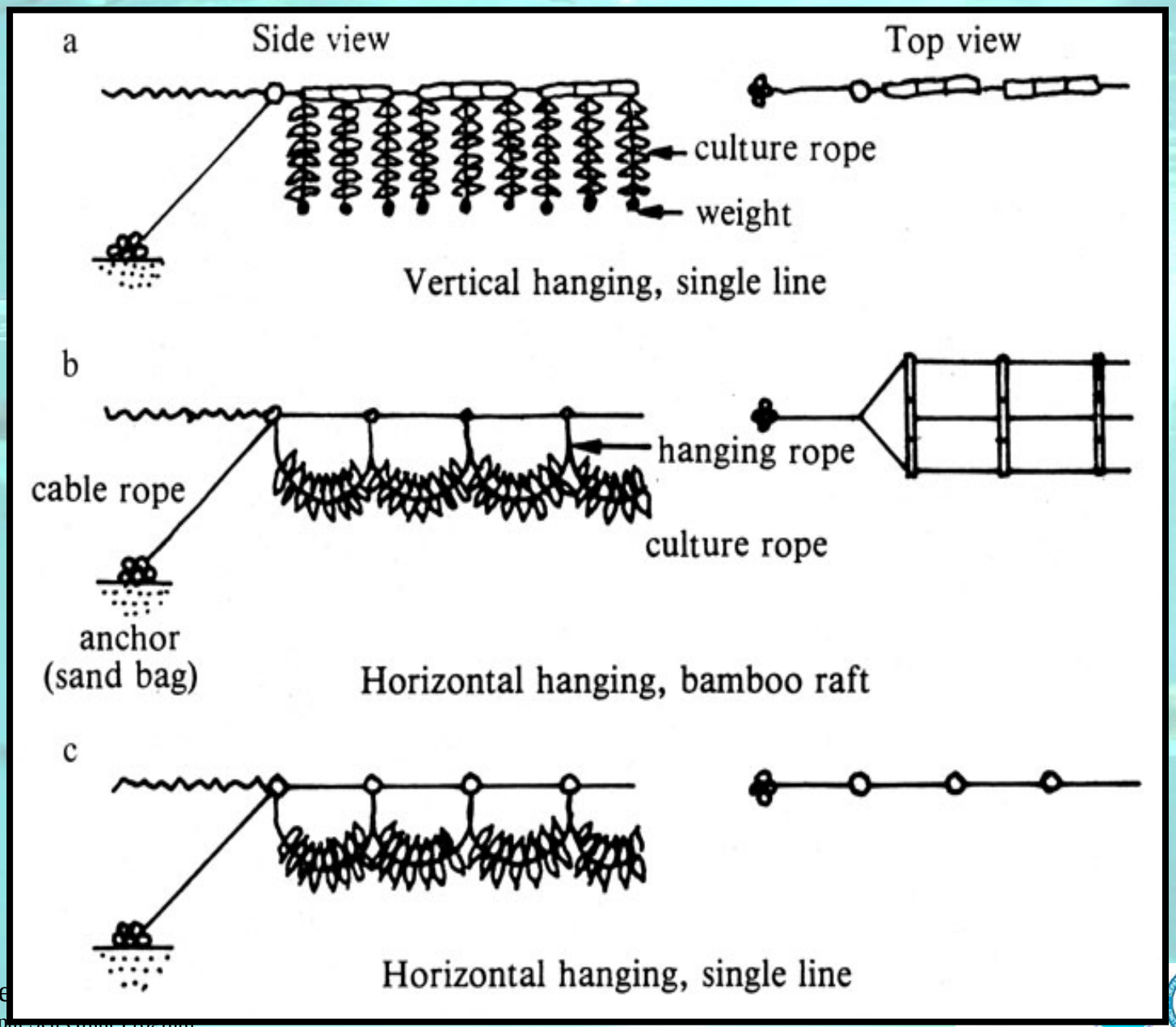
Methods for *Undaria* cultivation



N and P Removal Table, Xincon Bay

	N		C		C:N	P
May-00						
K. alvarezii **st 3**	**2.69 (0.26)**		**28.64 (0.63)**		**12.72 (0.92)**	**0.112 (0.007)**
Nov-00						
K. alvarezii **st 1**	**1.69 (0.12)**		**30.64 (0.41)**		**21.16 (1.18)**	**0.154 (0.005)**
K. alvarezii **st 2**	**1.50 (0.28)**		**28.61 (1.65)**		**22.56 (2.79)**	**0.144 (0.024)**
K. alvarezii **st 3**	**1.60 (0.05)**		**31.69 (0.38)**		**23.08 (0.94)**	**0.187 (0.005)**
K. alvarezii **st 4.1**	**1.33 (0.12)**		**27.95 (2.33)**		**24.47 (0.28)**	**0.223 (0.011)**
K. alvarezii **st 4.2**	**1.09 (0.01)**		**26.60 (0.18)**		**28.56 (0.30)**	**0.209 (0.004)**
Jan-01						
K. alvarezii **st 1**	**1.32 (0.20)**		**25.58 (1.22)**		**22.90 (2.66)**	**0.17 (0.01)**

Annual Production in Xincun Bay (1999)	Potential nutrient removal by algae		
		N	P
2000 mt	May	53.8 mt	2.24 mt
	November	28.8 mt	3.66 mt

Yarish, 2000)

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Role of Fish in a Balanced Ecosystem

- Every species of fish have a unique role within aquatic ecosystems.
- Kemp (1997) estimated that fishery harvests accounted for about 10% of total nitrogen removal.
- Enell and Ackefors (1991) estimated 9.5 Kg of P and 78 Kg of N per ton of typical salmon farm.
- Inputs of nutrients from fish aquaculture into nutrient poor waters can increase food-web interactions and careful placement within the ecosystem can contribute to ecosystem balance. (McVey 2002)

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Cobia Circling Central Spar

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Market size Cobia in PR

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Substrate in PR at 600 lbs Day

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Close up of Sand Bottom in Puerto Rico

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Polyculture of algae, fish and crustaceans

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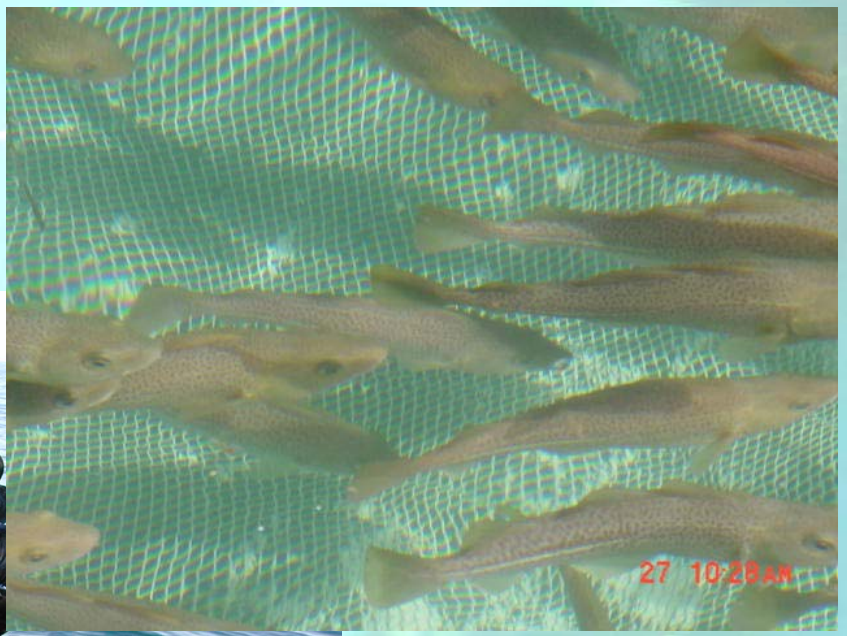
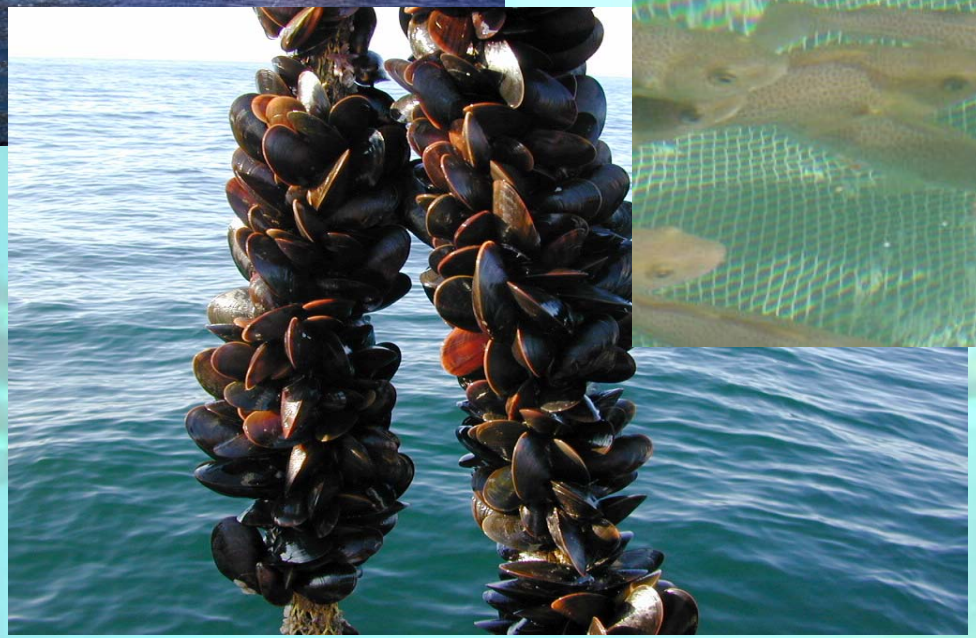
The University of New Hampshire Open Ocean Aquaculture Demonstration Project





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OOA is a component of NOAA/UNH CINEM


rock&roll

Substrate Photos Near Cage (780 lbs/day) vs Control

Near Cage

Control

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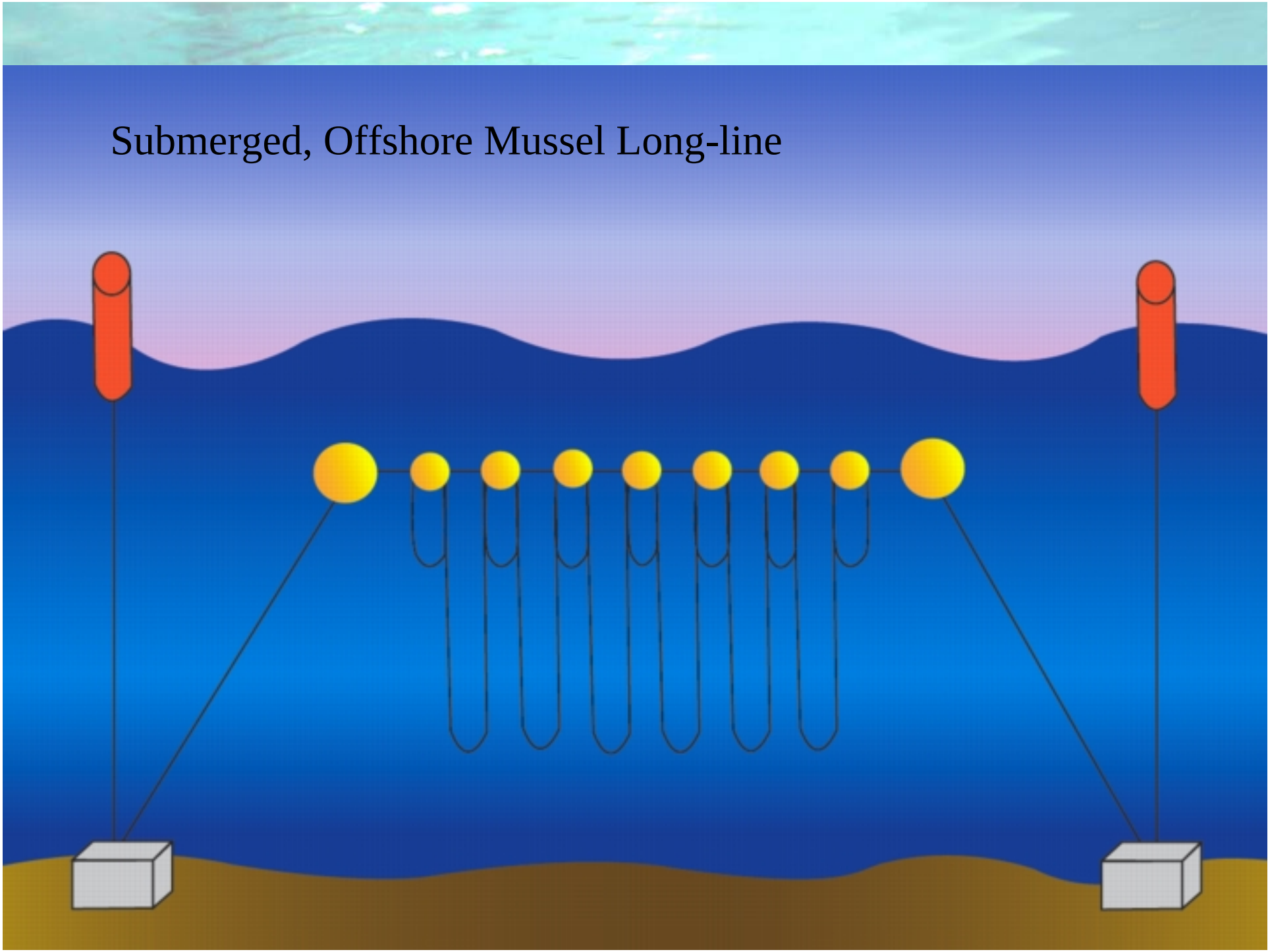
Submerged, Offshore Mussel Long-line



Submerged Mussel Lines in NH

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Market Sized Mussels on Ropes

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Hawaii Offshore Environmental Observations

- Maximum Feed/Day. 3000 pounds. Time: 3 years.
- Water Depth: 130 feet. Current: 10-20 Cm/sec.
- Inorganic N: No systematic changes for nitrite or nitrate at any station but some measurable change at cage rim for ammonia after feeding(temporal), reduced to 5 micrograms/liter, at 100 meters but no change at 400 meters.
- Total Organic N: % of organic N in sediments .3-.5%
- Benthic fauna: Change from polychaetes/amphibods dominant to 3 times higher biomass of nematodes under cage, 80 m less, 400 m with no change.
- Fish: 24 species, large schools of jacks (Decapturus and Caranx), Seriola, sand bar sharks, Moi, filefish.
- Invertebrates: Bryozoans, hydroids, algae.

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Summary of Environmental Observations

- Inorganic nitrogen concentrations are not changed significantly except at the net.
- Organic nitrogen in sediments no change at levels up to 3000 pounds of food per day
- Benthic communities will shift to more nematodes vs. polychaetes/amphipods at higher levels of organic N.
- Fish and large invertebrate species diversity and biomass will increase near and on offshore cages.
- Oxygen levels and benthic appearance have not changed and support biota under cages.

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Take Home Message

- Aquaculture can be used to place ecological function into aquatic ecosystems.
- Offshore systems can serve as habitat and a food source for valuable marine species without exceeding carrying capacity.
- We need to use ecosystem based management and utilize natural biological/ecological function as a means to create balanced and healthy ecosystems.

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